2000

VR, where do you really want to go tomorrow? - a retrospective on eight years of VR-related NRC studies

Zyda, Michael

VR, where do you really want to go tomorrow? -

a retrospective on eight years of VR-related NRC studies

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Talk Outline

Zyda Bio in NRC Reports

NRC Report Review

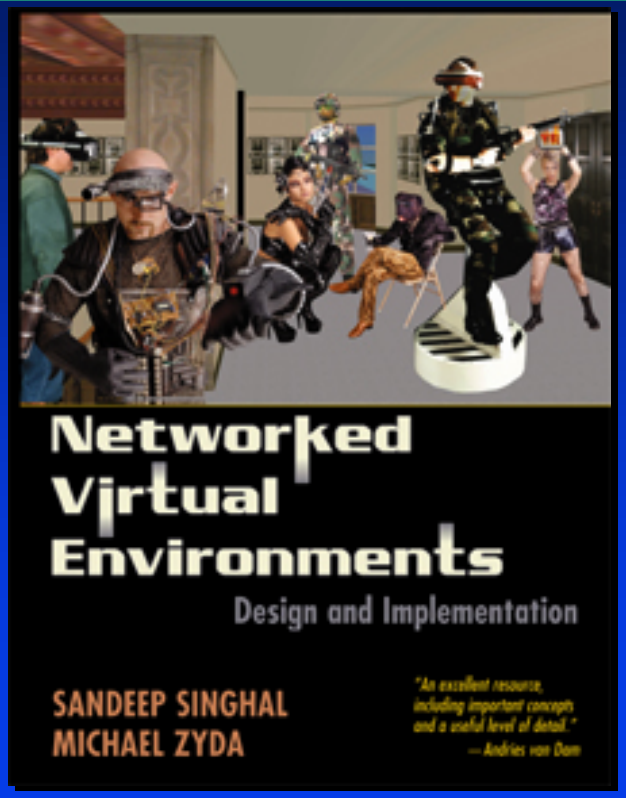
Where do we really want to go tomorrow?

What we should invest in

An education we need to provide

A lab we should build …

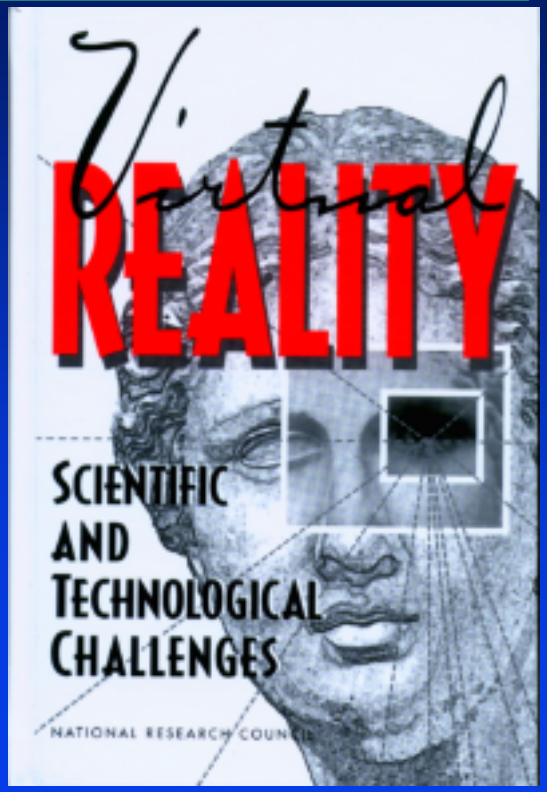
Zyda Bio



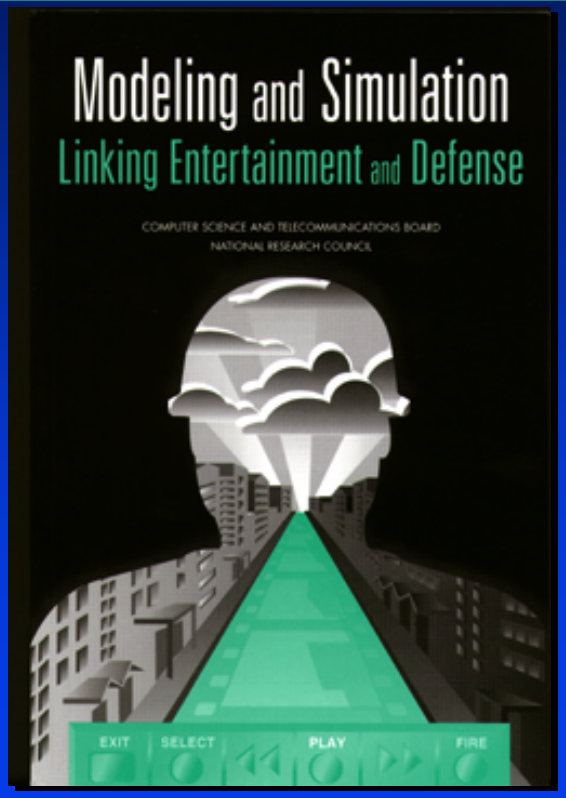
Professor Zyda has directed the NPSNET Research Group at the Naval Postgraduate School since its creation in 1986. His research is on software architectures for large-scale, networked virtual environments.

Zyda Bio - NRC 1992 - 1995

Zyda was a member of the NRC Commission on Behavioral & Social Sciences report "Virtual Reality - Scientific & Technological Challenges"



Zyda Bio - NRC 1996 - 1997



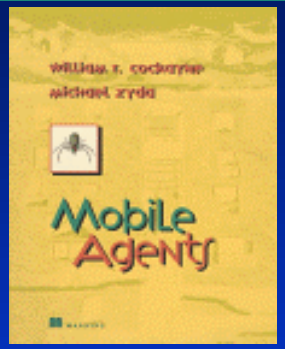
Professor Zyda chaired the NRC Computer Science & Telecommunications Board report "Modeling & Simulation - Linking Entertainment & Defense"

Michael Zyda - NRC 1998 - 2000

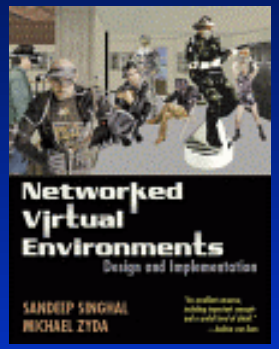
Professor Zyda is a member of the NRC Aeronautics & Space Engineering Board Committee on Advanced Engineering Environments, which has produced two reports on how NASA should design space systems in the future (2015), using VEs of course!

Zyda Bio from the High Level

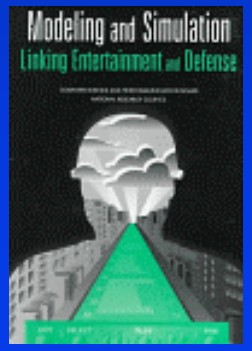
1995



1997



1999



2000

So what does all this bio stuff tell us (or not)?

1) That I like to sit through NRC committee meetings and write their silly reports!

2) That maybe I have some sort of high-level view of where we all want to go and what we ought to do to get there.

3) That maybe I'm wrong, that VR does not require any long term work and that all you need is a background from the business side of the entertainment industry to do research in VR. ;>)

What have we done?

Let's ramble through the Research Agendas for some of these NRC reports in brief to see what we have done & what remains to be done ...

- We will do this in brief, focusing on the things that play a part in our vision ...

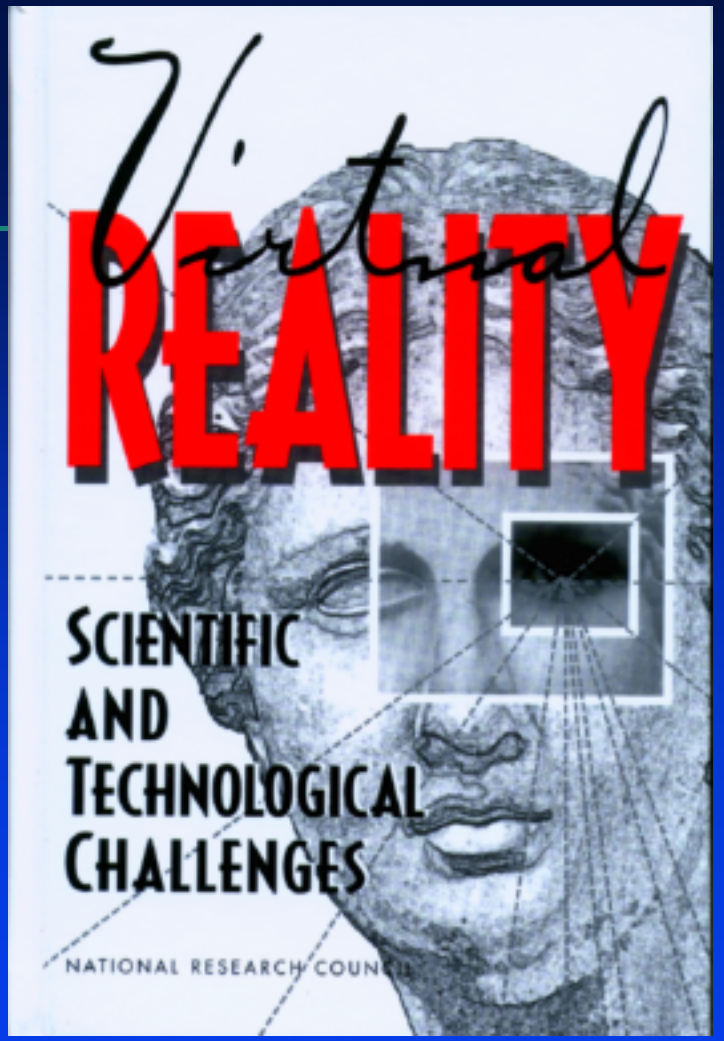
Virtual Reality Research Agenda

Some psychological considerations

Development of improved synthetic environment technology

Application domains

Evaluation of synthetic environment systems



Psychological Considerations

Psychological studies organized around the following objectives - Development of a comprehensive, coherently organized review of theory and data on human performance characteristics from the viewpoint of SE systems. Including basic sensorimotor resolution, perceptual illusions, info. transfer rate & manual tracking.

Psychological Considerations

Development of cognitive models that will facilitate effective design of VE systems for purposes of education, training and information visualization. Development of improved understanding of the possible deleterious effects of spending substantial portions of time in SE systems.

Psychological Considerations

Development of a theory that facilitates quantitative predictions of human responses to alterations in sensorimotor loops for all channels, with special emphasis on - Degradations in performance resulting from deficiencies in SE technology (e.g. in the form of distortions, time delays and system noise). Supernormal performance achievable through introduction of purposeful enhancing distortions. Radical sensorimotor transformations that arise, for example, in connection with the use of sensory substitution or strongly non-anthropomorphic telerobots. Methods of accelerating both adaptation to various types of alterations and readaptation to normal conditions. Channel interaction effects that occur with multimodal interfaces. Factors governing the occurrence, kind and magnitude of sopite sickness from SE exposure. Factors governing the strength of subjective telepresence and its relationship to objective performance.

Research Agenda

Development of Improved Synthetic Environment Technology

Human-Machine - Support of research on visual displays, haptic interfaces and locomotion interfaces - HMD; Tool-handle interfaces; Locomotion interfaces. **Position Tracking & Mapping** - A multiphase research & development approach - Conduct research & development on mechanical & inertial trackers. Explore the possibility of obtaining improved cost-effectiveness in tracking by using hybrid systems. Carefully monitor commercial developments in magnetic, acoustical and optical trackers, in eye trackers, and in trackers directed toward registration problems in augmented reality. If market forces do not drive the development of these trackers, federal research support is urged. **Testing & Evaluation** - The establishment of a set of standards or an independent laboratory to evaluate SE interface devices.

Development of Improved Synthetic Environment Technology

Computer Hardware - No aggressive federal involvement in computer hardware development in the SE area at this time. Hardware development remain largely a private-sector activity. Should serious lags in development occur, the gov't might then consider strategies for leveraging private-sector development efforts.

Research Agenda

Development of Improved Synthetic Environment Technology

Software - A major unified research program be created that focuses on those areas of development directly related to the generation, implementation, and application of VEs. Multimodal human-computer interactions. Rapid specification & rendering of visual, auditory and haptic images. Models & tools for representing & interacting with physical objects under multimodal conditions (including automated model acquisition from the real world). Simulation frameworks. A new time-critical, real-time operating system suitable for VEs. Registration of real and virtual images in augmented-reality applications. Navigational cues in virtual space. Behavior of autonomous agents. Computer generation of auditory and haptic images.

Networking

Standards - The federal government provide funding for a program (to be conducted with industry & academia in collaboration) aimed at developing network standards that support the requirements for implementing distributed VEs on a large scale. **Open-VE Net** - Funding of an open VE network that can be used by researchers, at a reasonable cost, to experiment with various VE network software developments and applications.

Research Agenda

Application Domain Recommendations

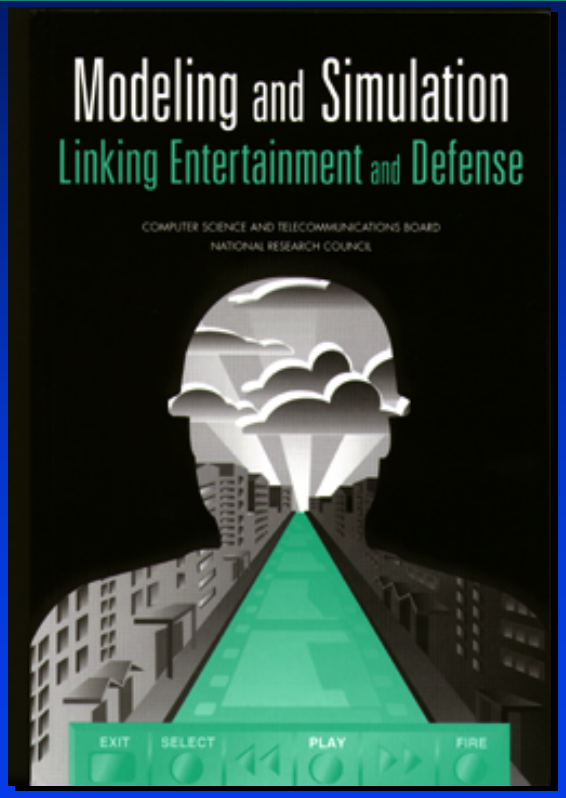
Four Application Domains - design, manufacturing & marketing; medicine & health care; hazardous operations; training. Research needs in these domains should be used as one of the principal means to focus SE technology development & testing.
Two projects for special attention - Modeling the human body for purposes of medical education, surgical planning and providing explanations of procedures and outcomes to patients; Studying the transfer of knowledge and skill gained in training in a VE to performance in a real-world task environment.

Evaluation of Synthetic Environment Systems

The federal government encourage the SE system developers it supports to include a comprehensive evaluation plan in the early design stages of their research projects. The federal government help coordinate the development of standardized testing procedures for use across studies, systems and laboratories, particularly in those areas in which the private sector has not acted.

Research Agenda

Modeling & Simulation - Linking Entertainment & Defense



The NRC report concluded with a research agenda in support of defense/entertainment modeling & simulation ...

NRC Research Agenda

Technologies for Immersion

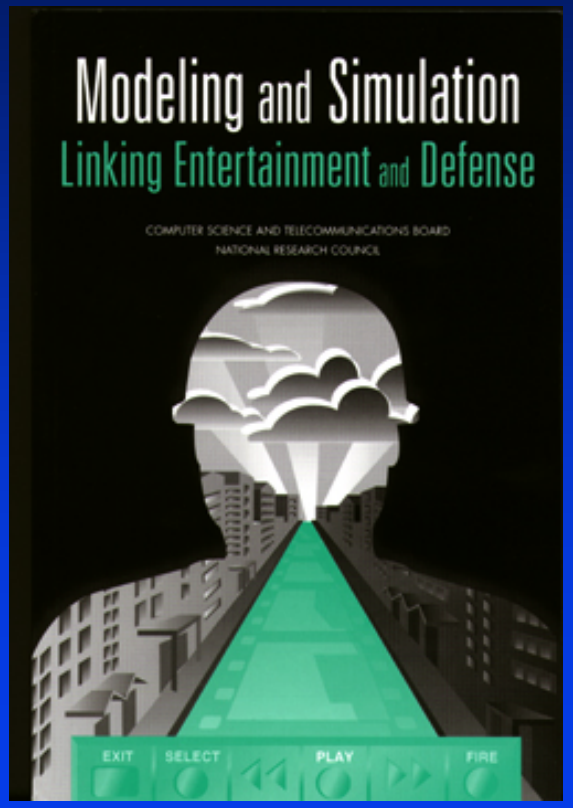
Networked Simulation

Standards for Interoperability

Computer Generated Characters

Tools for Creating Simulated Environments

New Educational Paradigms

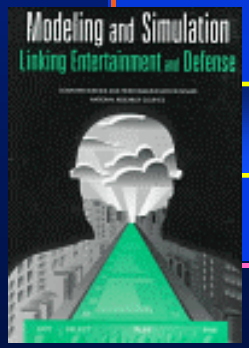


Technologies for Immersion

Image generation - real-time, computer graphic generation of complex imagery, HDTV, DVD, next generation delivery systems, novel display technologies, handheld and body-worn devices.
Tracking - technologies for keeping track of human participants in virtual environments.
Locomotion - technologies that allow participants to walk through virtual environments while experiencing hills, bumps, obstructions, etc. **Full sensory interfaces** - technologies for providing a wide range of sensory stimuli: visual, auditory, olfactory, and haptic. **Novel sound systems** - generation and delivery for both interactive and recorded media.

Networked Simulation

Multicast and area of interest managers - to facilitate the development of large-scale, media-rich, interactive, networked VEs.
High bandwidth networks - experimentation and utilization of next-generation Internet technologies for large-scale, networked virtual environments, and collaborative M&S development and application.
Wireless - handheld delivery systems.
Latency-reduction - techniques for predictive modeling in distributed simulations.
VE architectures for interoperability - Network software architectures for scalability, composability & dynamic extensibility.
Standards for interoperability



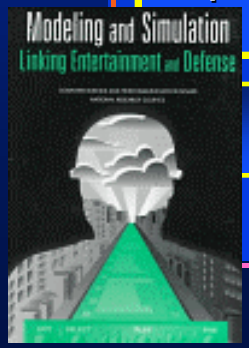
Research Agenda

Tools for Creating Simulated Environments

Virtual environment generation & manipulation - tools for managing the development of large-scale, high fidelity, computer graphics databases, tools that allow rapid retrieval of information, feature extraction, creation, & simplification. **Compositing** - hardware & software tools that allow designers to form composite images with images taken from multiple sources (live-action footage, 3D models, sensors) . **Interactive tools** - tools that use a variety of input devices to construct models and simulations. **Production tools** - rapid digitization & construction of virtual sets & interactive environments, interactive exploration of camera angles, lighting, exploration of effects & their integration with film/video/interactive.

Computer-Generated Autonomy

Adaptability - computer generated characters that can modify their behavior automatically. **Learning** - computer generated characters that can modify their behavior over time. **Individual behaviors** - computer-generated characters that accurately portray the actions & responses of individual participants in a simulation. **Human representations & models** - authentic avatars that look, move, and speak like humans. **Spectator roles** - ways of allowing observers into a simulation. **Aggregation & deaggregation** - the capability to coalesce smaller units into larger ones and separate them back into smaller ones. **Story line engines** - content production and simulation prototyping. Technologies for autonomous, real-time story direction and interaction. **Physically-Based Modeling**



Research Agenda

NRC Report - Advanced Engineering Environments

The NRC AEE study had the goal of providing NASA some guidance as to how to design space systems of the future (~2015) in an "advanced engineering environment".

- The Director of NASA wanted us to hypothesize about how we could get to such an AEE by the year 2015 & to suggest a technological pathway.

So how do you draft a technological roadmap?

What we did first on the committee was to draft a science fiction story about how a particular NASA engineer got called while on vacation at the beach in the year 2015 and asked if she could please revise her engine design.

- The details in the story are along the lines of what we would like her to be able to do tomorrow in the AEE …

So where do we really want to go tomorrow?

Tomorrow we will have ...

Let's make some assumptions.

- Effectively infinite computing power.
- Effectively infinite 3D graphics capability.
- Effectively infinite bandwidth.

Tomorrow we will have ...

Speeds ...

- 1,500 Mhz to 300 Ghz clock rate computers.
- 200M+ to 4.8B textured polygon/second range.
- 100 Mbps to 100 Bbps networks ...
- GBs of on-board memory.
- Handheld, wireless, cigarette pack-size, run all-day ...
- Connected to sun-glass weight HMD displays.

So I think that what I would really like simply ...

Is to be able to work at the beach or just about anywhere.

- What I would like to be able to do is put on my HMD glasses, pull up the models I am working on, be able to manipulate them from wherever I am using hand gestures, with my simulation running in real-time & providing me a real-time visual display of the simulation results, where I know those results/models are certified, where I can work with others, or intelligent agents, elsewhere, as all that I have done is seamlessly interoperable and communicable across any transmission medium.

And I want to do all this by the year 2015 ...

So what are the component parts required to make this happen?

- Work anywhere
- Lightweight HMD glasses
- Pull up the models I am working on,
- Be able to manipulate the models from wherever I am using hand gestures,
- With my simulation running in real-time & providing me a real-time visual display of the simulation results,
- Where I know those results/models are certified,
- Where I can work with others, or intelligent agents, elsewhere,
- As all that I have done is seamlessly interoperable and communicable across any transmission medium.

Implications

Work anywhere implies

- Wireless, handheld, high-speed net to the device ...
- Where are we today with handheld wireless devices?
  - Digital PCS phones - 14.4 Kbps
  - Ricochet laptop wireless modems - 48.4 Kbps
  - Lucent WaveLAN laptop PC card modems - 11 Mbps!

Lucent Technologies
Bell Labs Innovations

Is such wireless fast enough?

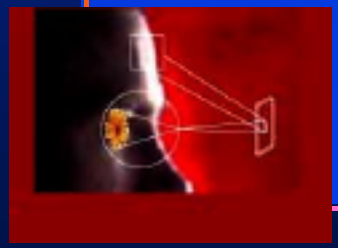
Well, 11 Mbps is pretty nice for wireless …

- If you look in the Singhal/Zyda book, you see that we can support 4,000 player entity interactions, and a video/audio stream with such a speed.
- So we can do a lot with such a speed, assuming our network interface can handle it.

Implications

Lightweight HMD glasses

- We are going to have to get way better at lightweight displays & invest more to make these happen.
  - These have been on the request list since the start of VR & have been mentioned in each of the NRC reports!
    - What do the VRD people say on this? SVGA today (800 x 600 x 1.5 lbs) --> possibly HDTV (1920 x 1080) tomorrow using MEMS and semiconductor LEDs.
      - 8000 x 8000 nowhere in sight, not lightweight ...



Today's VE Immersion Limitations

CAVEs & Capsules are what we do today because of these HMD limitations ...

Implications

Pull up the models I am working on,

- I think of this as “get-them-off-the-web of the future”.
  - We have a pervasive interface that can be used anywhere, to get any of the models we need.
  - So what makes up the web of the future?

Standards ...

XML, X3D and related tools seem to be a part of this future ability to just get our models off the web ...

X3D is is an XML-wrapped scenegraph compatible with multiple formats and the forthcoming web infrastructure.

- Imagine future Navy messages with 3D embedded content ...

Implications

Be able to manipulate the models from wherever I am using hand gestures,

- We must have perfect, non-intrusive tracking.
- We must know how to turn our sensed gestures into commands into our system's software.

Tracking answers?

Inertial tracker MEMs glued on our finger nails?

Perfect camera tracking?

- We are far away from technological solutions involving near-perfect body, limb or hand tracking.
- There is a lot more work to do.

Implications - Visual Display

With my simulation running in real-time & providing me a real-time visual display of the simulation results,

- Playstation 2 --> Rasterize 75M polygons/second and transform 66M polygons/second (2 March 2000 in Japan).
- Playstation 3 --> 1,000 times faster than that in three years? 66B polygons/second?

Playstation 2 & Descendents

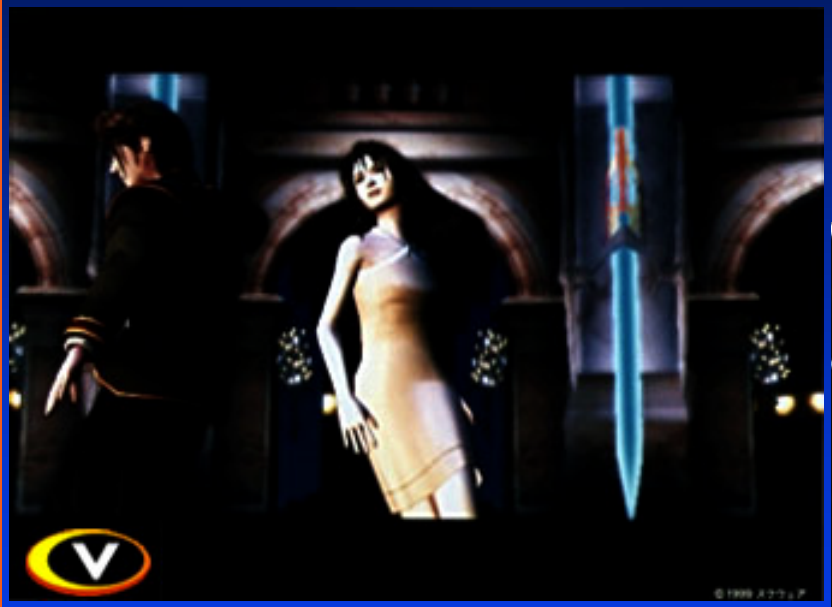
Platform	Polygons/Second	Display Resolution	Availability	Notes
Playstation 2	66M	640 x 480	Mar-00	Emotion Engine & Graphics Synthesizer
				Emotion Engine is the CPU & has 13M transistors
				0.18 micron process.
				$1.1B fab!
				$472M for Emotion Engine fab
				$660M for the Graphics Syn. Fab.
Creative Workstation	10 x PS-2	1920 x 1080/60p	2000	Parallel faster versions
Phase 1	660M?	(progressive)		of Emotion Engine & Graphics Synthesizer
				in Playstation 2.
Creative Workstation	100 x PS-2	1920 x 1080/60p	2002	Emotion Engine 2
Phase 2	6.6B?	24 to 75 fps		Graphics Synthesizer 2
				CPU 40M transistors
				0.13 micron process
				Will be able to handle movie production.
Creative Workstation	1000 x PS-2	4000 x 2000	2005/6	Emotion Engine 3
Phase 3	66B?	24 to 120 fps		Graphics Synthesizer 3
				Radically different architecture
				Server for theaters?
Playstation 3	66B?		2005/6	Based on Phase 3
Reference				
Yoshiko Hara, "Microprocessor Forum: Sony to us Playstation 2 technology for workstation line,"				
	7 October 1999, EE Times			

Visual Reality

Visual reality is 80M polygons/picture [Catmull,1984] & [NRC 95, pg. 252].

- 80M polygons/picture at 60 pictures/second (fps) is 4.8B polygons/second.
- We are talking about machines that can visually display computer images indistinguishable from reality.

Visual Reality



Visual Reality

Visual Reality

Visual Reality

Access to machines ...

- How does one get a Playstation 2 development kit?
- If you are a game developer and have special relations to Sony, no problem but if you are not ...
  - Its not like going to your SGI sales person and asking for a quote ...

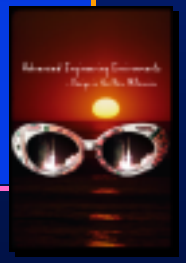
Implications

Where I know those results/models are certified,

- Model verification & validation - will we ever solve this for sure? No. But if we make our models available on the web, then we can get multiple, parallel, open testing of our results ...

Web-based data verification

NASA, other government agencies, and the private sector must support a dialogue, within the engineering profession, to create mechanisms that serve to insure the quality of data that is made available through the web (the "good engineering" seal of approval). This effort could be catalyzed by the advisory panel and initiated through a series of workshops organized by the agency with support from professional societies.



Implications

Where I can work with others, or intelligent agents, elsewhere,

- Working with others elsewhere implies we have standard ways for communicating.
- Intelligent agents --> Computer-generated autonomy (CGA).
  - NRC 97 suggests a sizable investment in CGA and points out that maybe we need to adopt entertainment industry ideas for this rather than your grandfather's AI ...

Computer-Generated Characters

- We want computer-characters in our net-VEs with whom we can interact in an intelligent fashion.
- We want autonomous behaviors for those characters.
- We want characters that can come in over the network and play with us, educate us, train us, characters that can learn and help guide the VE's story.

Computer-Generated Characters

We need software architectures that can provide:

- Adaptability - modify behavior automatically
- Learning - modify behavior over time, reinforcement learning.
- Agent-based - to allow for emergent behaviors.
- Behavior & Story Modeling
- High quality avatars

Computer-Generated Characters - The Sims

EXPERIENCE

- Create an endless variety of characters and families
- Follow a wide range of career paths
- Make friends, have conversations, insult neighbors, fall in love, have children ...

Implications

As all that I have done is seamlessly interoperable and communicable across any transmission medium.

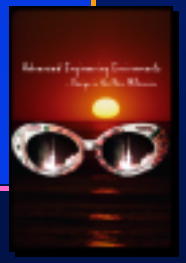
- Seamless interoperability, communicable across any transmission medium.
  - This is not your grandfather's HLA. This is a real, careful, considered approach to semantic interoperability in a distributed fashion.

Composability & Interoperability

Basic research in interoperability and composability should be supported within the flow of open Internet computing, not outside that flow under cover of government mandate.

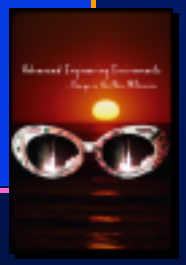
Solutions for interoperability and composability should be developed using open source guidelines in order to increase our software's reliability and widespread adoption.

Part of the research that must be supported is on the grand challenge issue of how, in general, we should develop interoperable component software architectures.



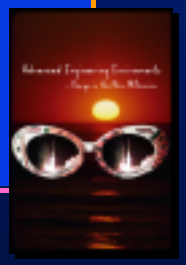
Composability & Interoperability

Engineering educational programs should include a more extensive educational foundation in software development, including component software architecture and solutions for composability and interoperability.



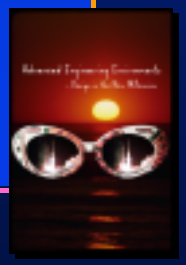
Composability & Interoperability

Government and industry need to encourage the development of an interoperability/composability broker (ICB) industry. The ICB industry will be tasked with componentizing, in open source fashion, the AEE software knowledge-bed of the late twentieth century.



Composability & Interoperability

Support consensus in the development of Internet-deployed software technologies, using open source guidelines. Avoid governmental and corporate mandates for programming language and operating system choice in the development of AEE systems.



So what should we invest in?

Research Agenda - Where to invest

Composability & Interoperability (web-based, open source, cross platform, component frameworks, semantic encoding, XML, X3D)

Computer-Generated Autonomy & Modeling Human & Organizational Behavior (agent-based simulation)

Technologies for Immersion (HMDs, CAVE/Capsules, lightweight tracking solutions, game platform utilization, multimodal interfaces, motion bases ...)

Research Agenda - Where to invest

Networked Simulation (area of interest management, persistent universes, web-based interoperability, dynamic protocols, wireless)

Componentized Physical Modeling

Human Systems (cognitive modeling,...)

& the VR community should leverage work done by the entertainment industry for VR research & application and not the other way around as some would have it. ;>)

Research Agenda - Where to invest

Applications

- Training
- A componentized virtual human model
- A national agenda in advanced engineering environments

How to carry out this investment

Need a directed educational program.

- The educational program needs to provide the underpinnings of the areas in which we plan to work.
  - The NPS MOVES academic program is a good prototype.

Scope of the MOVES Curriculum

Programming

Object-oriented programming, data structures, artificial intelligence, symbolic computing

Systems & Architecture

Computer systems principles, computer architecture, operating systems, distributed operating systems

Computer Graphics

Computer graphics, image synthesis, computer animation, computer graphics using VRML

Mathematical Fundamentals

Multivariable calculus, linear algebra, probability & statistics

Communications & Networks

Computer communications & networks, virtual environment network & software architectures, wireless mobile computing

Virtual Environments

Virtual world & simulation systems, human factors of virtual environments, training in virtual environments

Modeling & Simulation

Stochastic models, system simulation, physically-based modeling, simulation methodology, high & low-resolution combat modeling, modeling human & organizational behavior, agent-based autonomous behavior for simulations

Human-Computer Interaction

Interactive computation systems, human performance measurement, human performance evaluation, human factors in system design, C4I systems evaluation

How to carry out this investment

Need a focused research institute, not just a lot of small thrusts everywhere.

- We need to build a real, technical institute that carries out the specified VE research agenda.
- The institute needs to be lead by a VE researcher, with additional strong VE researchers for each major foci of our agenda.
- The institute needs a major, long-term funding stream ...


Any questions?
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VR